U. S. ARMY
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FORT EUSTIS, VIRGINIA

# EXPERIMENTAL RESEARCH

## DYNAMIC TEST OF AN AIRCRAFT LITTER INSTALLATION

One of a Series of Reports Pertaining to the
Dynamic Crash Test of a U.S. Army H-21 Helicopter

March 1963

*Contract DA-44-177-AMC-888(T)*

*TRECOM Technical Report 63-3*

prepared by :

AVIATION CRASH INJURY RESEARCH
PHOENIX, ARIZONA
A DIVISION OF
FLIGHT SAFETY FOUNDATION, INC.
NEW YORK, NEW YORK

**HEADQUARTERS**
**U. S. ARMY TRANSPORTATION RESEARCH COMMAND**
**Fort Eustis, Virginia**

This report was prepared by Aviation Crash Injury Research (AvCIR), a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-888(T). Views expressed in the report have not been reviewed or approved by the Department of the Army; however, conclusions and recommendations contained therein are concurred in by this Command.

On 12 September 1962, AvCIR, under contract to the U. S. Army Transportation Research Command, conducted a dynamic crash test of an H-21 helicopter. Among the several experiments aboard the aircraft was the installation of a standard U. S. Army litter/patient restraint system. This report, the first in a series of six reports to be published containing data derived from the crash test, presents information relative to the litter/patient restraint system experiment.

Action is being taken at this time by the Office of the Surgeon General, Department of the Army, and by this Command to implement the recommendations contained in this report.

FOR THE COMMANDER:

KENNETH B. ABEL
Captain TC
Adjutant

APPROVED BY:

WILLIAM J. NOLAN
USATRECOM Project Engineer

Task 1A024701A12101
(Formerly Task 9R95-20-001-01)

Contract DA-44-177-AMC-888(T)
TRECOM Technical Report 63-3
March 1963

# DYNAMIC TEST OF AN AIRCRAFT LITTER INSTALLATION
## One of a Series of Reports Pertaining to the Dynamic Crash Test of a U. S. Army H-21 Helicopter

By
James Schamadan, M. D.
James W. Turnbow, Ph. D.
Langston W. T. Weinberg

Technical Report
AvCIR 62-23

Prepared by
Aviation Crash Injury Research
a division of
Flight Safety Foundation, Inc.
2871 Sky Harbor Blvd.
Phoenix, Arizona

for

U. S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

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## ILLUSTRATIONS

## SUMMARY

This report presents an analysis of the crashworthiness characteristics of a standard litter/patient restraint system as installed in a helicopter which was subjected to a dynamic crash test.

On 12 September 1962, Aviation Crash Injury Research conducted a dynamic crash test of an H-21 helicopter. Several personnel restraint systems were installed in the aircraft to permit evaluation of performance under impact conditions. Included was a standard litter installation. Anthropomorphic dummies were placed on the litters. Accelerometers were mounted in the pelvic areas of the dummies, and tensiometer links were mounted on the litter support straps. A high-speed camera was positioned in the helicopter to record the action of the litter installation during the crash sequence.

Although the crash was considered to be survivable, the litter/patient restraint system failed completely. The details of the failures are discussed; and it is concluded that the military specifications covering litter/patient restraint systems are not realistic and, therefore, litter/patient restraint systems produced in accordance with these specifications do not provide adequate protection for the occupant under moderately severe, but potentially survivable, crash conditions.

## CONCLUSION

Based on the information contained in this report, it is concluded that military specifications pertaining to litter/patient restraint systems do not require sufficient strength to provide protection for the occupants in certain potentially survivable accidents.

## RECOMMENDATIONS

Based on the foregoing conclusion, it is recommended that:

1. A thorough investigation be initiated to develop realistic design criteria for litter/patient restraint systems.

2. Additional testing of litter/patient restraint systems consist of tests of the entire assembly as contrasted with the testing of single components.

3. Both static and dynamic tests be conducted on the litter/patient system. Dynamic tests should be conducted at acceleration and energy levels consistent with the conditions expected in moderately severe, but potentially survivable, accidents.

## INTRODUCTION

The problem of litter/patient restraint has never been thoroughly investigated in Army aircraft. The concept of air mobility as related to the transportation of sick or wounded personnel was proven during the Korean conflict. The state-of-the-art in aeromedical evacuation has since progressed rapidly with the introduction of newer techniques and specially designed aircraft. Among the most significant advancements is the concept of internal loading of patients in utility and cargo helicopters. Although the external-pod-type helicopter is still in use, the scope of this experiment was limited to the application of internal patient transport in rotary-wing aircraft. It is anticipated that the principles developed here will also have application in all types of aircraft that may be involved in aeromedical evacuation.

An investigation of all available accident records of the internally loaded helicopter ambulance revealed little data which could be used in an evaluation of the dynamic crash characteristics of any litter/patient restraint systems. Consequently, plans were made to include a standard litter/patient restraint system in the first dynamic crash test of an H-21 helicopter. This test was conducted by AvCIR for the U. S. Army Transportation Research Command on 12 September 1962.

## TEST OBJECTIVE

The objective of this experiment was to evaluate the crashworthiness of a standard, internally loaded litter/patient restraint system installed in a typical helicopter.

## DESCRIPTION OF TEST ARTICLE

A standard H-21 litter installation was used as the test article in this project. This installation normally consists of three litters, six litter handle tiedown brackets attached to the aircraft side structure, and three litter handle tiedown brackets attached to each of two straps suspended between fittings on the passenger cabin ceiling structure and cargo tiedown fittings on the floor.

Only the top and middle litters of the standard three-litter stack were used in this experiment because of a weight limitation of the test vehicle. Since the bottom litter of a normal three-litter stack attaches within a few inches of the floor, it was calculated that the gross effect of this litter/patient combination on the dynamic characteristics of the litter support system as a whole would be small. Experience gained from previous dynamic crash tests of helicopters of similar construction indicated that the floor structure would deform upward on impact and contact the bottom litter. This deformation and subsequent litter contact would remove any load on the total litter support system which might be attributed to the bottom litter/patient combination. Therefore, a valid test of the litter/patient restraint system could be obtained with only two litters installed.

Three 1/4-inch nylon ropes were suspended from the cabin ceiling to three cargo tiedown rings in the floor to prevent interaction of this experiment with other experiments in the event that the litter support system failed. The addition of these ropes was the only alteration to the standard litter installation, and their presence had little effect upon the performance of the litter/patient system itself.

An anthropomorphic dummy was placed on each litter in a head-forward, supine position. The dummy occupying the lower litter was restrained by a standard single belt restraint system across the pelvic area, and the upper dummy was restrained by a standard single belt restraint system across the chest cavity. The complete precrash litter installation is shown in Figures 1 and 2.

Accelerometers were installed in the pelvic region of each anthropomorphic dummy to measure accelerations in the lateral, longitudinal, and vertical directions on the top litter patient and in the longitudinal and vertical directions on the lower litter patient. A force tensiometer was installed between the ceiling tie point and the litter support strap on both the forward and the rear litter support straps. These installations are shown in Figures 3 and 4.

**Figure 1. Litter Installation, H-21 Helicopter - Side View.**

**Figure 2. Litter Installation, H-21 Helicopter, Front View.**

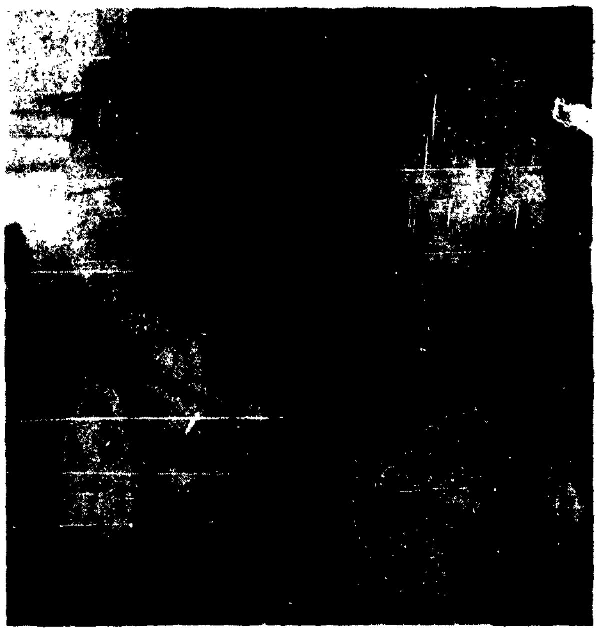


Figure 3. Accelerometer Installation in the Anthropomorphic Dummy Patients.

Figure 4. Force Tensiometer Installed in the Litter Support Strap System.

A high-speed 16mm motion picture camera and necessary auxiliary lighting were installed in a position to photograph the action of the litter/patient installation during the impact sequence. A photograph of this installation is presented in Figure 5.

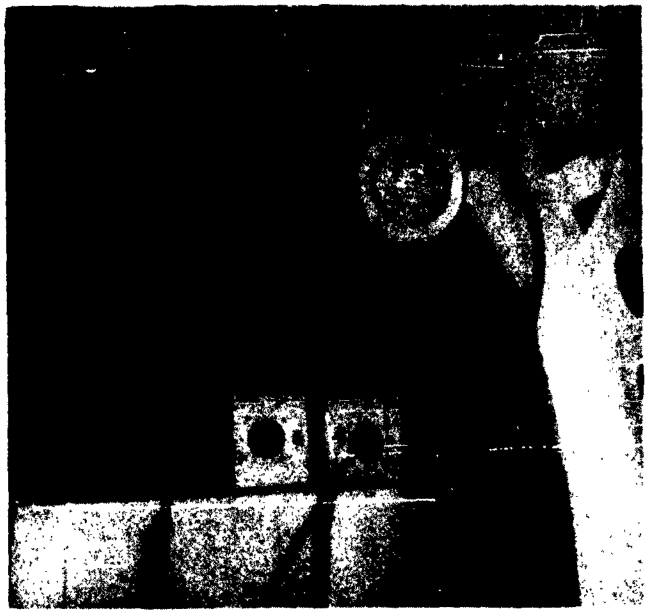


Figure 5. High-Speed Camera Installation for Photographing Litter/Patient Restraint System (Camera No. 4).

# TEST PROCEDURE

## DESCRIPTION OF TEST OPERATIONS

A drone control system was installed in the helicopter to allow complete remote control of the helicopter through the entire test flight. The actual flight flown during this test followed the profile shown in Figure 6.

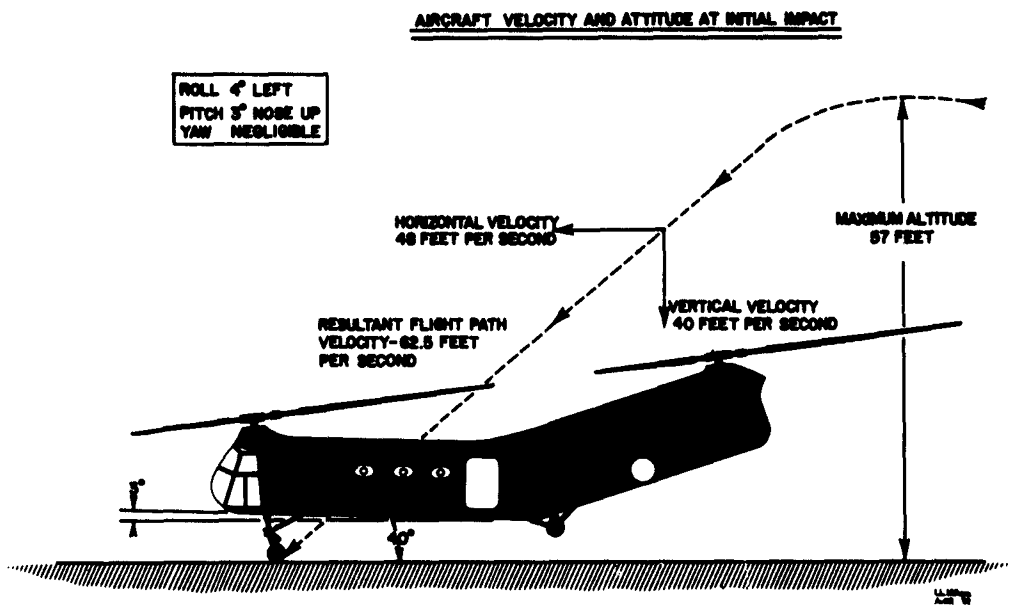



Figure 6. Test Conditions.

A report covering the more detailed mechanics of the test operation is being prepared at this time for release at a later date.

The accelerometers and force tensiometers were connected through a balance and sensitivity unit to a 500-foot umbilical cable which was connected directly to recording oscillographs located at a stationary point on the ground. A block diagram of the instrumentation system is presented in Figure 7.

Just prior to the test, an eight-step resistance calibration was made on all appropriate channels by connection of a calibration unit to the balance and sensitivity unit on the helicopter. The bridge battery voltage was monitored on one channel to record any change in the bridge voltage during the crash sequence. No voltage change was recorded.

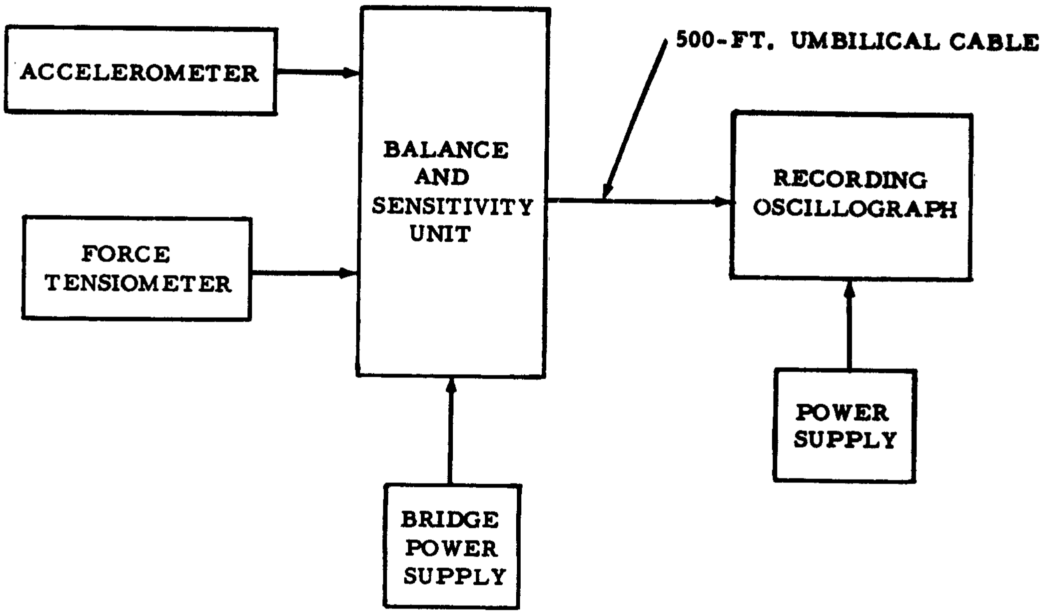



Figure 7. Instrumentation Data Recording System.

The high-speed camera and associated auxiliary lighting were controlled by a switch on the master control panel at the control point. During the descent, the cameras and lights were turned on manually by the instrumentation operator, and they were automatically turned off after a 10-second period by a time delay circuit.

The area covered by the high-speed camera is shown in Figure 8.

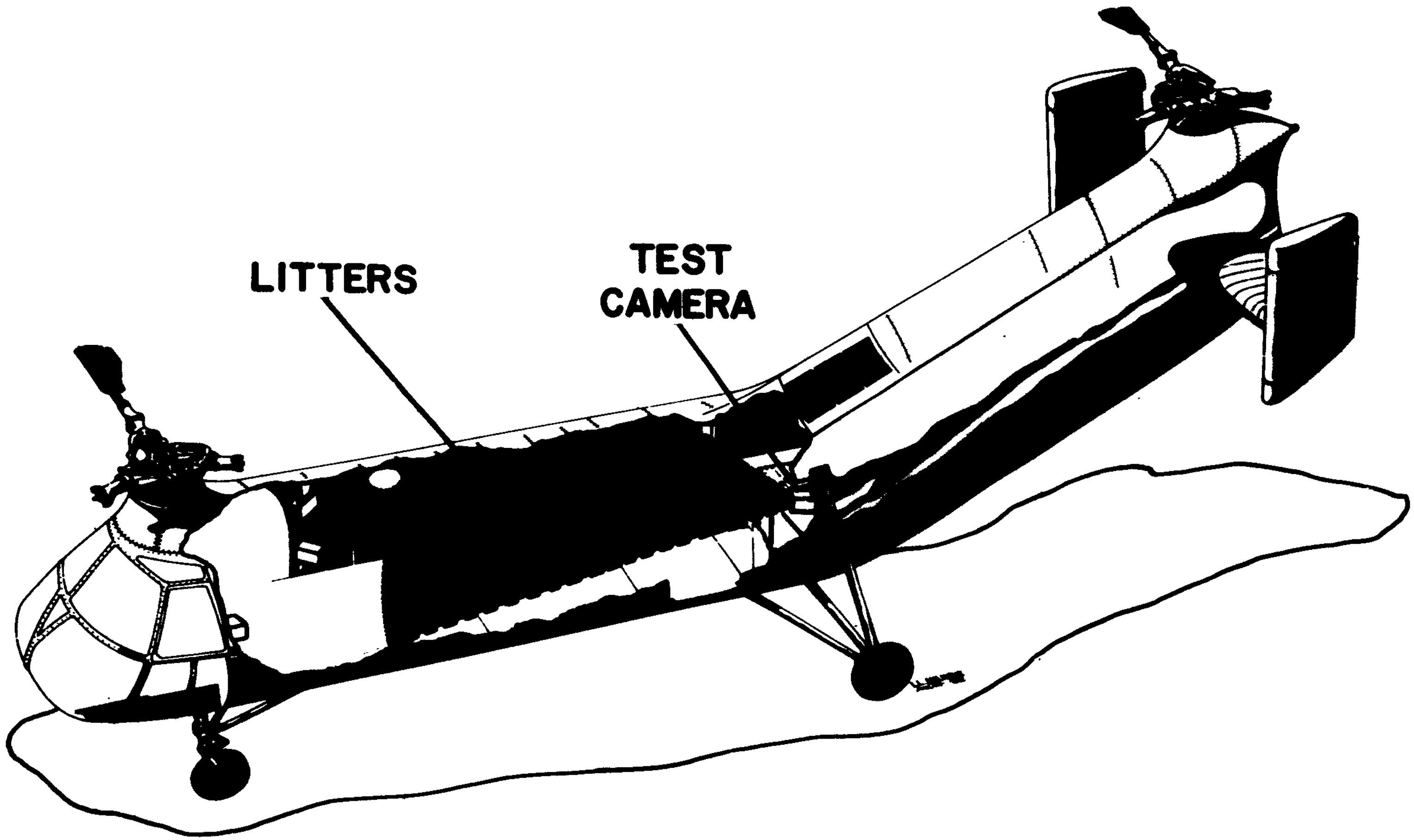



Figure 8. Camera Placement Diagram.

## INSTRUMENTATION

A list of the data acquisition system components related to this experiment is presented in the table.

INSTRUMENTATION

| Device | To Provide | Location | Specification |
|---|---|---|---|
| High-Speed Motion Picture Camera | Displacement/ time for helicopter and dummy kinematics data | 4 on ground 1 on aircraft | Photosonics 1B high G tolerance 500 fps 16mm Ektachrome ER 430 |
| Normal-Speed Motion Picture Camera | General photographic coverage | 4 on ground | 2 Kodak 16mm 64 fps 2 Bolex 16mm 24 fps Kodachrome II |
| Electrical Accelerometers | Acceleration sensing | 5 in dummies 3 on cabin floor | Statham A5A-50-350 and A5A-100-350 |
| Tensiometer | Force sensing | 2 each in litter strap | AvCIR 2500 lb load link |
| Recording Oscillograph | Amplitude-time records of transducer outputs | 4 each at ground control point | CEC Model 5-114-26 Channel recording oscillograph with related power supplies |
| Photographic/ Oscillographic Data Correlation Device | Zero time for camera film and oscillograph record | 2 each | Photo flash bulbs mounted in field of view of cameras. Firing pulse to bulbs recorded on oscillograph record for correlation |
| Voltage Generator | Timing for high-speed cameras | Ground control point | 115 Volt AC generator, 60 cps timing pulse |
| Fairchild Flight Analyzer | Horizontal and vertical speed of the helicopter | 500 feet perpendicular to center of flight path | FDFA-044 |

## TEST RESULTS

### LITTER SIDE ATTACHMENTS

All four of the litter-fuselage attachment brackets failed in the manner illustrated in Figure 9. The bracket assembly consists of a clip device to hold the litter pole. The clip is bolted to a formed aluminum bracket which is, in turn, attached by screws to a casting on the bulkhead.

Figure 9. Litter Side Attachment Failure.

The application of a downward load on the clip places both shear and bending moment on the aluminum bracket. The moment puts the lower face of the bracket in compression with a tension load on the upper screws and upper portions of the bracket. The brackets all failed by a tension-type fracture in the area of the upper screws.

The casting on the bulkhead in no case showed evidence of failure.

## LITTER STRAPS

The aisle support for the litters is provided by the same type of clip as used on the wall. These clips are attached at appropriate points to 1-inch-wide by 1/8-inch-thick nylon straps, which, in turn, are attached to both the floor and the ceiling of the aircraft cabin as shown in Figure 2.

This test points out two weaknesses of the strap restraint system. The first, pertinent to the H-21 installation only, is the failure of the ceiling attachment for the forward strap. The strap passes through a casting which is bolted to a thin metal bulkhead near a lightening hole (no doubler is provided). The casting is connected by two bolts in line with the axis of the strap so that all force in the strap acts on the same portion of the bulkhead. The failure of this strap connection is shown in Figures 10 and 11.

Figure 10. Failure of the Ceiling Structure at the Forward Litter Strap Attachment Point.

Figure 11. Forward Litter Strap Ceiling Attachment - Postcrash View.

The second weakness concerns the longitudinal restraint value of the clip. The litter handle is placed in the clip and secured by a nylon web hooked over the handle. This arrangement provides good vertical and lateral restraint to the capacity of the system, but gives very little restraint longitudinally. This is the principal reason why the rear strap did not fail like the front, since the litter handles at the rear slipped forward and out of the clip, thus unloading the strap. The forward handles push against the clip in a forward deceleration, which in this experiment prevented the pullout, but caused the upper fitting installation to be overloaded to failure.

## LITTERS

A postcrash photograph of the litters is presented as Figure 12. The lower litter* retained its basic shape; however, permanent deformation of the litter poles occurred. The floor beneath the litters was not badly deformed; thus, the litter and occupant impacted upon a relatively flat surface. The left rear stirrup hooked onto one of the nylon ropes, which tended to hold it in the same relative position. The outboard forward handle also caught in the unused bottom litter bracket (see Figure 9), causing the fabric to tear along the outboard

*Note that this litter would have been the center litter of the normal three-litter installation. (See Figure 2.)

pole. This greatly helped to check the forward motion of this litter after the failure of its restraint system. A permanent set of about 5 inches was retained in the litter poles, as shown in Figure 13.

Figure 12. Litter System - Postcrash View.

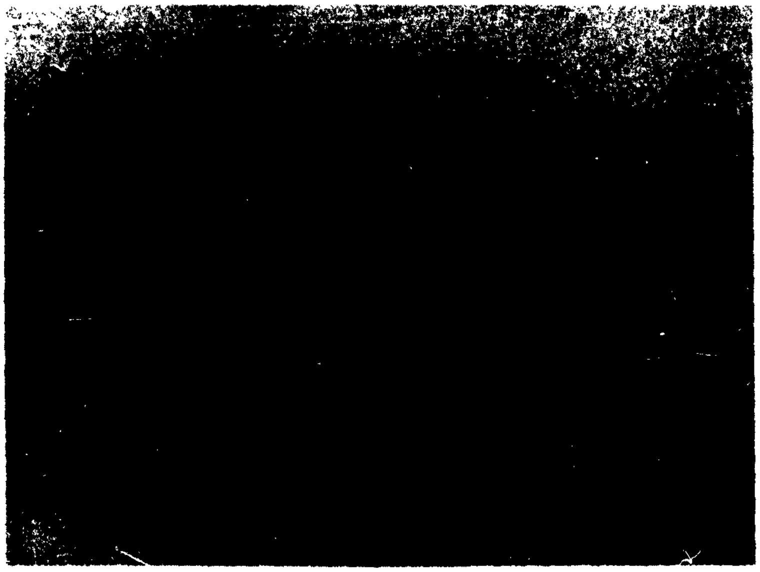


Figure 13. Permanent Deformation of the Lower Litter. (Litter shown here inverted.)

The upper litter sustained considerably greater damage. After failure of its restraint system, its forward and downward motion was unchecked until it contacted the lower litter and occupant.

One litter pole was bent with a permanent set of 6 inches, as shown in Figure 14. The other pole had a permanent set of 3 inches. The rear spreader bar was collapsed and the left rear stirrup was broken free. (See Figure 12.) This action was due to the shearing deformations induced in the litter because of the absence of longitudinal restraint on the inboard poles.

Figure 14. Permanent Deformation of the Upper Litter. (Litter shown here inverted.)

## LITTER PATIENTS

Failure of the litter support system allowed the dummy patients to move headfirst toward the forward part of the cabin. The upper litter patient's buttocks were at about the position of the lower patient's head, as shown in Figure 12. The upper dummy was also rotated and was essentially clear of the litter itself. The lower dummy remained in its litter but shifted forward about 24 inches with respect to the litter.

## FUSELAGE STRUCTURE DEFORMATIONS

The entire lower structure of the forward fuselage section, including fuselage skin, floor support structure, and lower sections of body frames, was crushed in the primary impact of the helicopter on the runway. The left side of this lower structure was crushed more severely than the right side, since the impact occurred with approximately 4 degrees of left roll. The floor was distorted throughout the cargo compartment, but it maintained an essentially continuous surface except in localized areas.

Generally, the fuselage structure above the normal troop seat attachment points (approximately 17 inches above the floor line) remained intact on both sides of the aircraft, while the structure below this line was crushed extensively.

Although this impact was severe, the crash is classified as potentially survivable because the occupiable areas of the fuselage remained essentially intact. The shock loads imposed upon the aircraft by the impact were attenuated by the crushing of the fuselage structure below the occupiable space. A postcrash view of the litter/patient area in the helicopter is presented as Figure 15.

Figure 15. Litter/Patient Floor Area and Side Panel Deformation.

## TEST DATA EVALUATION

The accelerometer and force tensiometer time-history plots recorded during the test are presented in Figure 17. A kinematic drawing, taken from the high-speed 16mm film, is presented in Figure 18. This drawing shows the sequence of events occurring at the litter station during the test.

The following observations have been made and may be followed through reference to Figures 17 and 18:

1. No appreciable deceleration (horizontal or vertical) was imposed upon either dummy from the time of impact of the nose gear of the H-21 (time zero) to about 0.19 second, at which time the bottom dummy contacted the floor due to deformation in both the airframe and in the litter support system. A 50G vertical acceleration of over 10 milliseconds duration was recorded in the pelvic region of the lower dummy following contact with the floor.

2. The maximum loads in the litter straps were recorded at approximately 900 pounds per strap. Assuming that the litter brackets supported an equal load, the total load would then be 4 x 900 = 3,600 pounds on the complete system. This load would produce 9G on the 400-pound mass of the two dummies. The vertical acceleration records (Figures 17-4 and 17-6) indicated accelerations of this order of magnitude up to contact of the lower dummy with the floor.

3. Both the upper and lower litters slipped out of the brackets attached to the rear support strap with subsequent reduction in load in the strap. The rear strap and its support system did not fail.

4. The forward litter strap reached a load of over 900 pounds at the time of separation of the rear litter handles from the rear strap. This load dropped to about 800 pounds at 0.21 second and then immediately dropped to zero as the support at the cabin ceiling failed.

5. The contact of the bottom dummy with the floor of the aircraft resulted in oscillatory "longitudinal" acceleration as measured in the pelvic region of the dummy. A positive (forward) longitudinal acceleration of 50G is seen to have occurred at 0.21

second (Figure 17-5) in conjunction with the 50 (plus) G vertical acceleration. This positive acceleration was due to the orientation of the dummy and thus of the accelerometer at contact, allowing a negative "vertical" acceleration to be recorded as a positive "longitudinal" acceleration. A similar situation existed for the upper dummy, as seen in Figure 17-3. This action is illustrated in Figure 16.

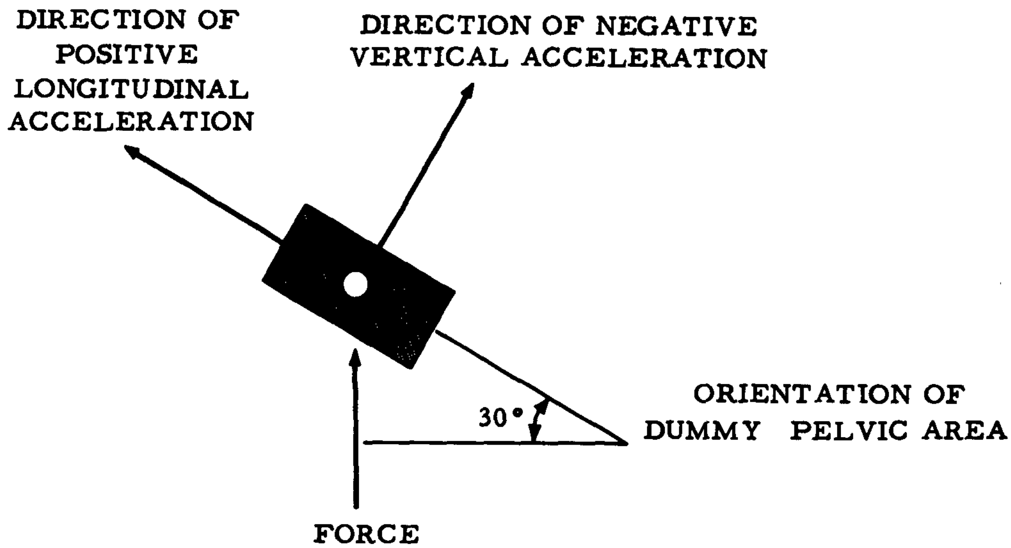
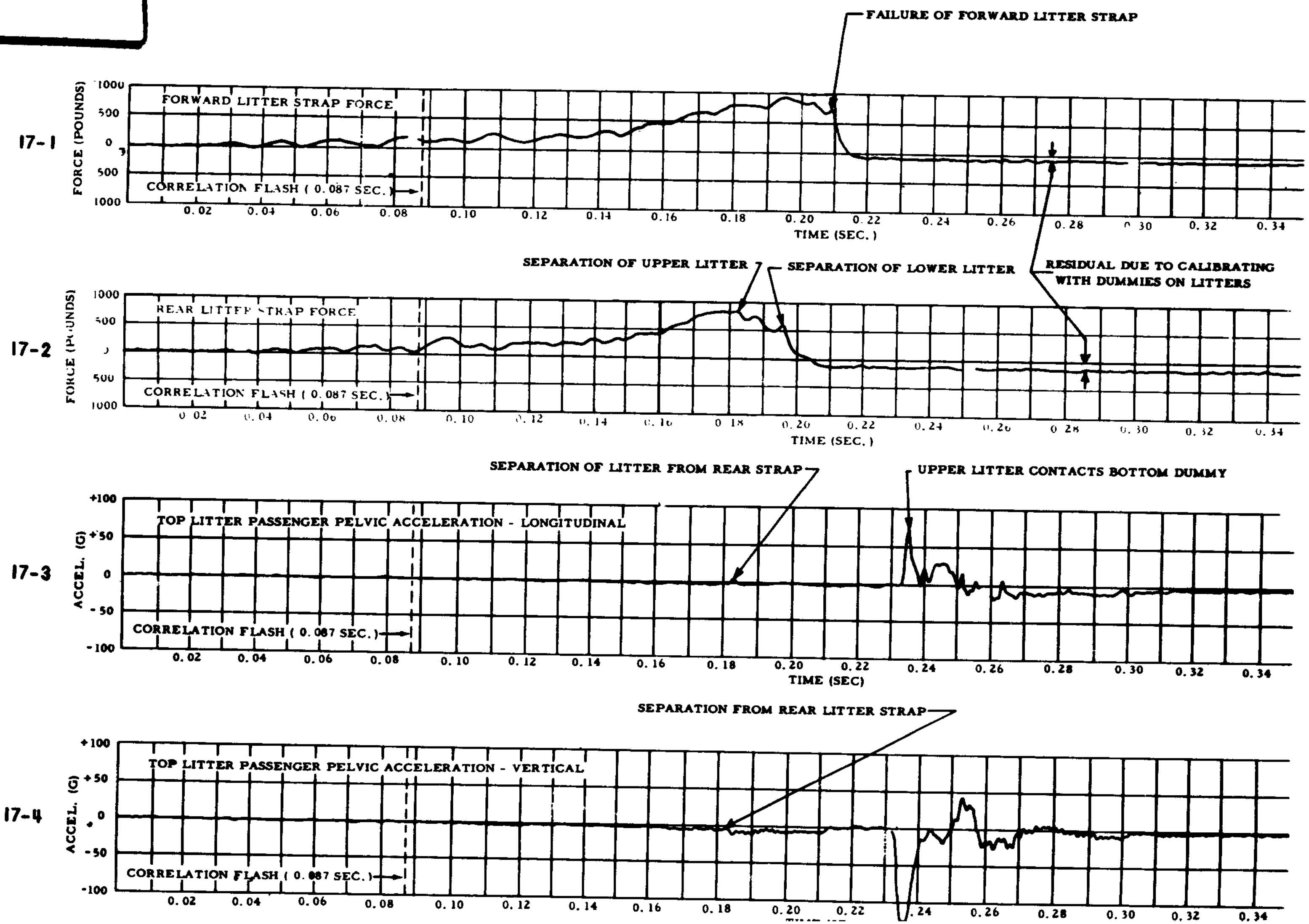
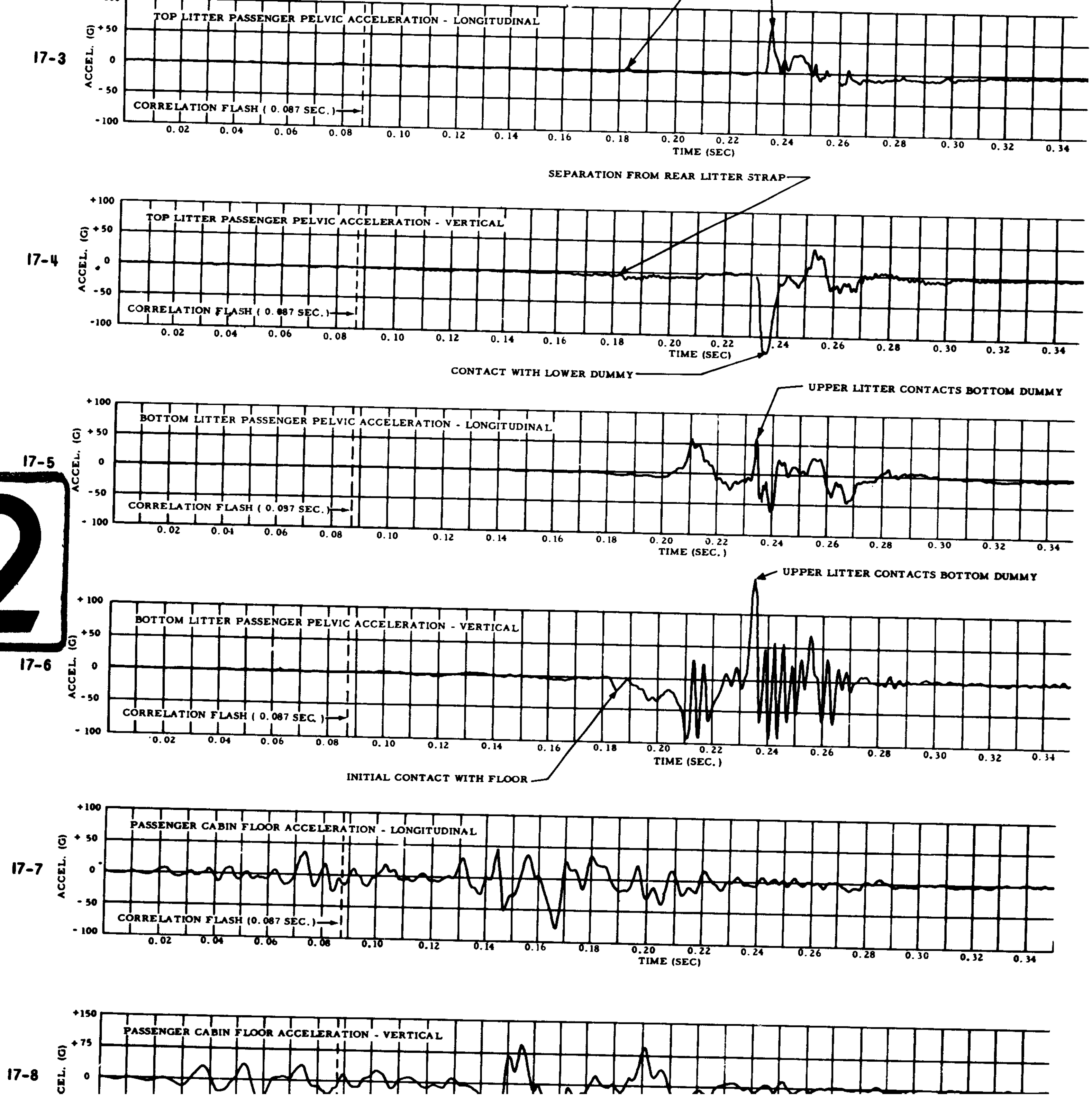



Figure 16. Free-Body Diagram of the Upper Dummy Pelvic Region.

6. The top litter patient impacted the lower dummy at 0.23 second, as shown in Figure 18. A "vertical" acceleration of 125G (see Figure 17-4) and a simultaneous longitudinal acceleration of 70G (Figure 17-3) were recorded. A positive vertical acceleration of 150G (Figure 17-6) was also recorded in the lower dummy. A positive acceleration in this instance implies that downward load has been applied as was obviously the case here.

H-21 HELICOPTER CRASH TEST T-7




17-3
TOP LITTER PASSENGER PELVIC ACCELERATION - LONGITUDINAL
ACCEL. (G)
+50
0
-50
-100
CORRELATION FLASH ( 0.087 SEC.)
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34
TIME (SEC)
SEPARATION FROM REAR LITTER STRAP
17-4
TOP LITTER PASSENGER PELVIC ACCELERATION - VERTICAL
ACCEL. (G)
+100
+50
0
-50
-100
CORRELATION FLASH ( 0.087 SEC.)
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 .24 0.26 0.28 0.30 0.32 0.34
TIME (SEC)
CONTACT WITH LOWER DUMMY
UPPER LITTER CONTACTS BOTTOM DUMMY
17-5
BOTTOM LITTER PASSENGER PELVIC ACCELERATION - LONGITUDINAL
ACCEL. (G)
+100
+50
0
-50
-100
CORRELATION FLASH ( 0.097 SEC.)
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34
TIME (SEC.)
UPPER LITTER CONTACTS BOTTOM DUMMY
17-6
BOTTOM LITTER PASSENGER PELVIC ACCELERATION - VERTICAL
ACCEL. (G)
+100
+50
0
-50
-100
CORRELATION FLASH ( 0.087 SEC.)
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34
TIME (SEC.)
INITIAL CONTACT WITH FLOOR
17-7
PASSENGER CABIN FLOOR ACCELERATION - LONGITUDINAL
ACCEL. (G)
+100
+50
0
-50
-100
CORRELATION FLASH (0.087 SEC.)
0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34
TIME (SEC)
17-8
PASSENGER CABIN FLOOR ACCELERATION - VERTICAL
+150
+75
0

2

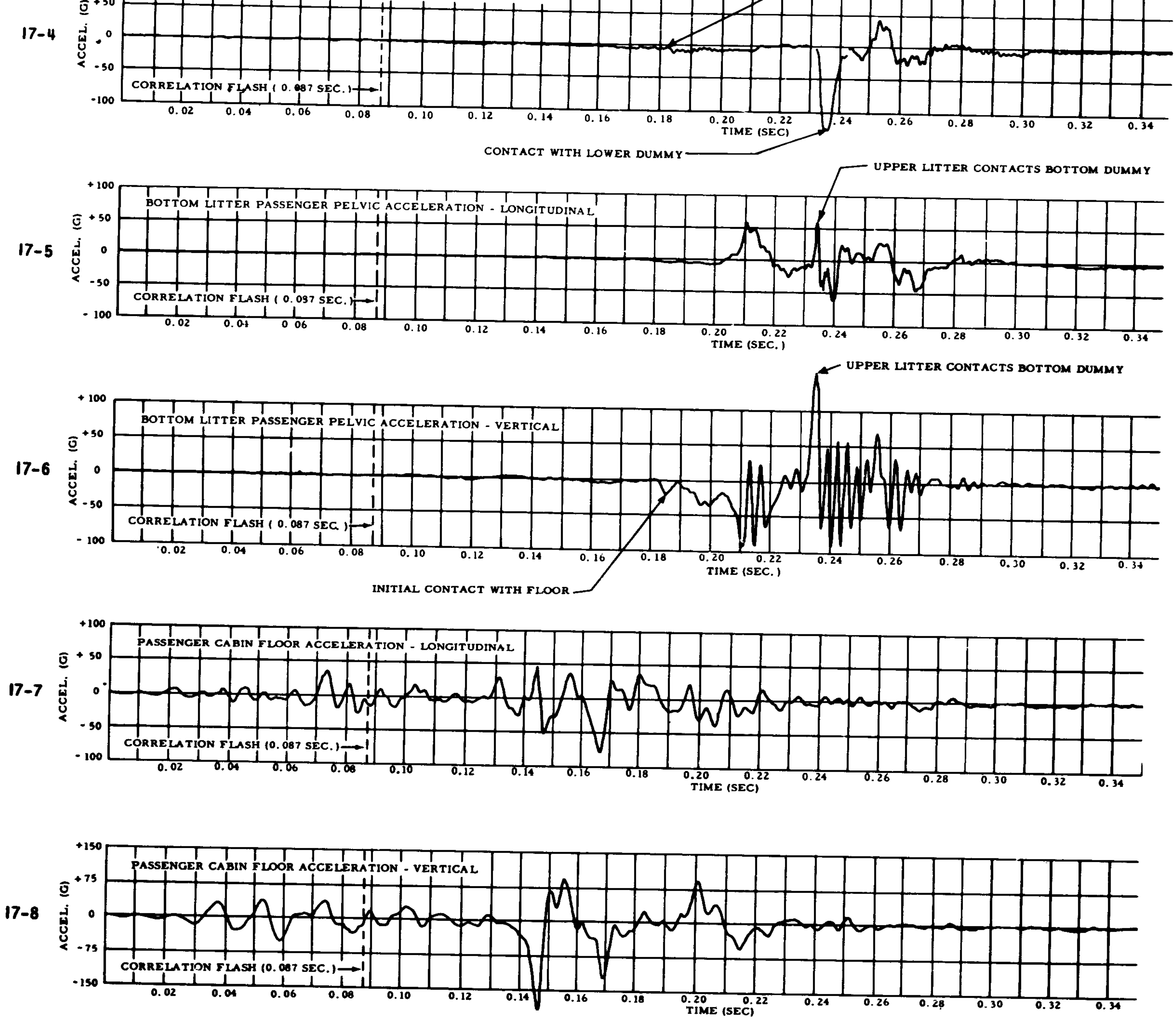
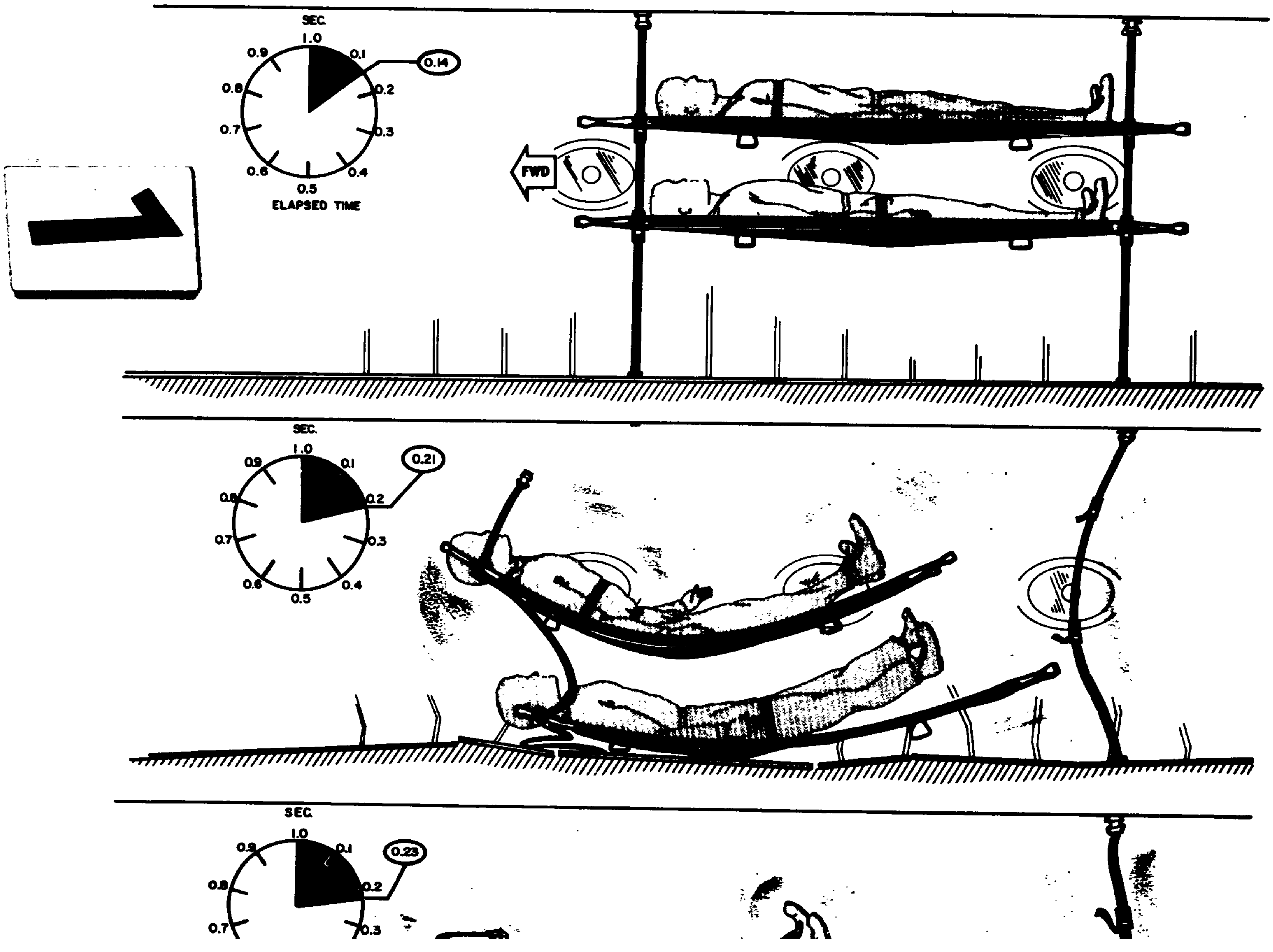
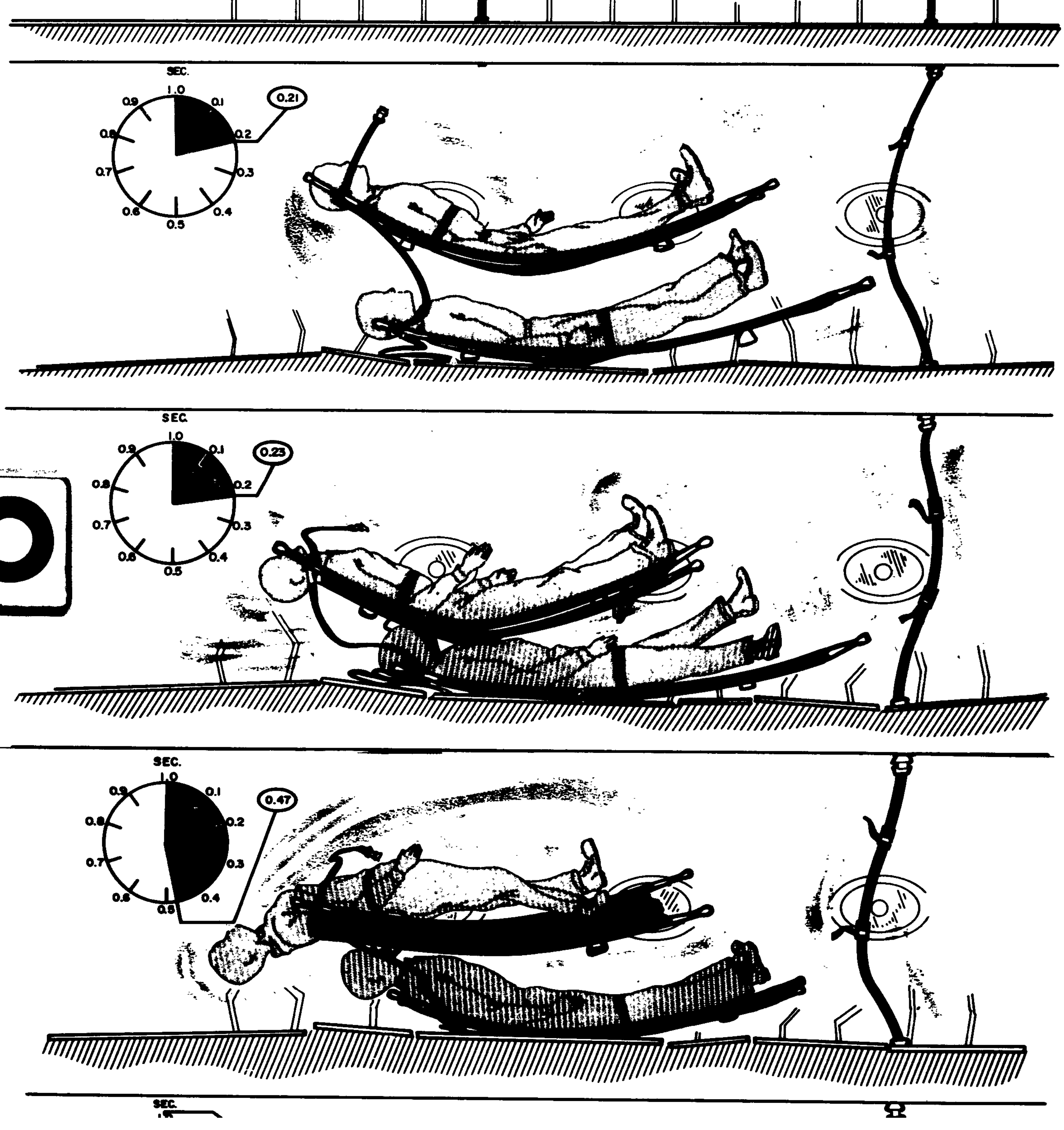



**Figure 17. Accelerometer and Force Tensiometer Time-History Plots.**


1
SEC.
1.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.14
ELAPSED TIME
FWD
SEC.
0.21
SEC.
0.23

2



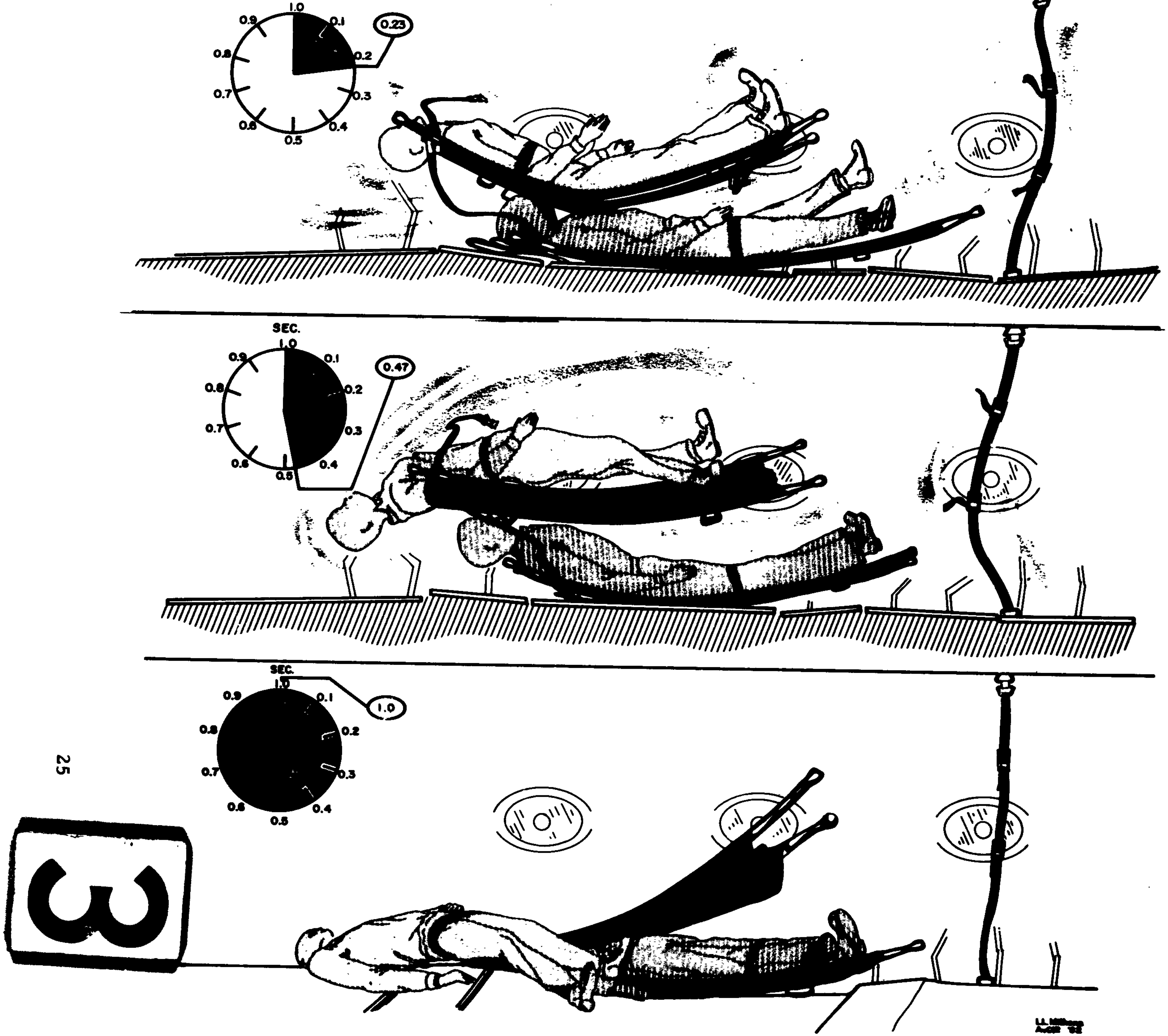



Figure 18. Kinematic Drawing of Litter Restraint System During the Crash Impact Sequence.

## TEST EVALUATION

The litter/patient restraint system used in the crash test was a standard military system. All of the components met individual military specifications. As shown by the tensiometer readings, the entire system began to fail under moderate loads.

Litter installation requirements, MIL-A-8865(ASG), provide that supports and attachment fittings for litters shall be designed so that they will carry to the primary structure a 250-pound litter load multiplied by the following ultimate load factors.

| | |
|---|---|
| Forward | 8G |
| Lateral | 1.5G |
| Vertical | 4.5G down, 2.0G up |

The specifications, however, require only static testing of components. Static tests do not account for combined forces that are characteristic of dynamic situations. When the litter/patient restraint system is assembled in actual use, the conditions are no longer ideal. There is no way to ensure that the straps are tightened to the same tensions. The clips that hold the litter handles in the installation described in this report are awkward and difficult to tighten, leading to loss of restraint under the longitudinal loads which will often exist in actual crashes.

The results of this test of a litter/patient restraint system are considered to be typical for all recent litter installations for internally loaded helicopters. It is apparent that the system as a whole is not capable of maintaining survivable conditions for the occupants in potentially survivable crashes of the severity demonstrated.

## DISTRIBUTION

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| ONR | 5 |
| BUWEPS, DN | 5 |
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| MCLFDC | 1 |
| MCEC | 1 |
| USCG | 1 |
| Canadian LO, USATSCH | 3 |

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| ASTIA | 10 |
| USAMRDC | 2 |
| HumRRO | 2 |
| DAA | 3 |
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| ODCSPER, DS | 1 |
| USAMCAFO | 2 |
| BMS, AMSFTB | 2 |
| BMS, AMTD | 1 |
| SG, AvnB | 5 |
| AFIP | 2 |
| USMC, Arlington | 1 |
| USAFDFSR, Norton AFB | 1 |
| USABAAR | 5 |
| USAAHRU | 1 |
| US Army Rep, USNASC | 1 |
| USNASC, NAS | 2 |
| NavAMC | 3 |
| NADC | 1 |
| WADD | 2 |
| ASML | 2 |
| CARI, FAA | 2 |
| NLM | 2 |
| AF, FTC | 2 |
| HUSTWO | 2 |
| ARDS, FAA | 2 |
| BFS, FAA | 2 |
| BAM, FAA | 2 |
| BUS, CAB | 2 |
| APD, USPHS | 2 |
| APRSS, DRG | 2 |
| FSFI | 5 |
| AvCIR | 100 |
| USSTRICOM | 1 |
| USAMOCOM | 3 |
| USAMC | 8 |
| NLM, Bethesda | 1 |

Aviation Crash Injury Research, Phoenix, Arizona, DYNAMIC TEST OF AN AIRCRAFT LITTER INSTALLATION, J. Schamadan, M. D., J. W. Turnbow, Ph. D., and L. W. T. Weinberg, TRECOM Technical Report No. 63-3, March 1963, 29 pp. -illus. - Contract DA-44-177-AMC-888(T) USATRECOM Task 9R95-20-001-01, Unclassified Report

Report is made of dynamic testing and analysis of crashworthiness characteristics (Cont'd.)

UNCLASSIFIED

1. Dynamic Test of Aircraft Litter Installation

2. Contract DA-44-177-AMC-888 (T)

Aviation Crash Injury Research, Phoenix, Arizona, DYNAMIC TEST OF AN AIRCRAFT LITTER INSTALLATION, J. Schamadan, M. D., J. W. Turnbow, Ph. D., and L. W. T. Weinberg, TRECOM Technical Report No. 63-3, March 1963, 29 pp. -illus. - Contract DA-44-177-AMC-888(T) USATRECOM Task 9R95-20-001-01, Unclassified Report

Report is made of dynamic testing and analysis of crashworthiness characteristics (Cont'd.)

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